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Illinois Fruit and Vegetable News

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a newsletter for commercial growers of fruit and vegetable crops



"We are what we repeatedly do. Excellence, then, is not an act, but a habit." Aristotle

Address any questions or comments regarding this newsletter to the individual authors listed after each article or to its editor, Rick Weinzierl, 217-333-6651, weinzier@uiuc.edu. The ***Illinois Fruit and Vegetable News*** is available on the web at: http://www.ipm.uiuc.edu/ifvn/index.html . To receive email notification of new postings of this newsletter, call or write Rick Weinzierl at the number or address above.

In this issue ...

A too-busy schedule in early and mid December kept me from completing the issue of this newsletter scheduled for that time, so this is a combination of issues 18 and 19. Be sure to note the schedule for upcoming extension programs, especially the Illinois Organic Production Conference January 11-12, and the Illinois Specialty Crops Conference January 17-19. The Illinois Specialty Crops Conference is our only statewide winter program for all fruit and vegetable producers, and it offers a great opportunity to hear production, pest management, and marketing updates, to talk with other growers, and to meet with suppliers.

Rick Weinzierl (217-333-6651, weinzier@uiuc.edu)

Upcoming Meetings and Programs

January 11-12, 2006, Illinois Organic Production Conference ...
... at the Interstate Center, 2301 West Market Street, Bloomington, Illinois. The program runs from 1:00 p.m. on January 11 through 3:30 P.M. on January 12, and the pre-registration fee is $85. The agenda includes a general session on January 11 and breakout tracks on January 12 focusing on field crops, specialty crops (including fruits and vegetables), livestock, and miscellaneous issues. For more information, contact Dan Anderson at 217-333-1588 or by email at aslan@uiuc.edu. Program information is available online at http://www.aces.uiuc.edu/asap/orgconf/ConfSchedule.htm.

January 17-19, 2006, Illinois Specialty Crops Conference ...
... at the Crowne Plaza, Springfield, Illinois. This is our statewide program organized by the University of Illinois Extension and the Illinois Specialty Growers Association. The program will begin at 9:45 a.m. on January 17, with general sessions and concurrent tracks on fruits, vegetables, and herbs, as well as a fourth track on cross-cutting issues including farm marketing, insurance, liability, labor, food safety, and irrigation. A full-day post-conference workshop focusing on tomato and sweet corn production and pest management is scheduled for January 19. The program is available online at the Illinois Specialty Growers Association web site (http://www.specialtygrowers.org/; click on the "More" link under the Convention Update heading on the right side of the page). For more information, contact Diane Handley at the Illinois Specialty Growers Association, 309-557-2107 or handley@ilfb.org.

January 23-25, 2006, Indiana Horticultural Congress ...
... at the Adam's Mark Hotel near the Indianapolis airport. The program includes sessions on farm marketing, agri-tourism, and fruit and vegetable production and pest management. Topics on the vegetable program include greenhouse diagnostics, downy mildew of cucurbits, pumpkin production, vegetable herbicides, sweet corn and melon varieties, and beneficial insects. For details, contact Danielle Sheese at 765-494-1301 or by email at dlinback@purdue.edu. The program will be posted on the web at http://www.hort.purdue.edu/hort/ext/hortcongress/.

January 26, 2006, Illinois Horseradish Growers School ...
... at the Gateway Convention Center in Collinsville, Illinois. The program will include updates on breeding efforts, tissue culture for maintaining germplasm, research on disease-free propagation, hydroponics, soil amendments, postharvest storage, insect scouting, an IPM survey, and variety trial evaluations. For more information, contact Elizabeth Wahle at 618-692-9434 or by email at wahle@uiuc.edu.

February 7 and 8, 2006, Southern Illinois Tree Fruit Schools ...
... at Mount Vernon on February 7 and Hardin on February 8. For more information, contact Elizabeth Wahle at 618-692-9434 or by email at wahle@uiuc.edu, or as the dates approach check for information at "News for Southern Illinois Growers" at: http://web.extension.uiuc.edu/regions/hort/.

February 9, 2006, Kankakee Area Vegetable Growers School ...
... at the Kankakee County Extension Office in Bourbonnais, IL. For more information, contact Maurice Ogutu at 708-352-0109 or by email at ogutu@uiuc.edu, or contact James Theuri at Jtheu50@dogwood.itcs.uiuc.edu.

February 10, 2006, Illinois-Wisconsin (Stateline) Fruit and Vegetable Conference ...
... for more information, contact Maurice Ogutu at 708-352-0109 or by email at ogutu@uiuc.edu,

February 16, 2006, Southern Illinois Vegetable School ...
... at the Mount Vernon Holiday Inn. For more information, contact Elizabeth Wahle at 618-692-9434 or by email at wahle@uiuc.edu, or as the dates approach check for information at "News for Southern Illinois Growers" at: http://web.extension.uiuc.edu/regions/hort/.

February 20-22, 2006, Missouri Small Fruit and Vegetable Conference ...
... at the Clarion Hotel and Conference Center, Springfield, MO. The program includes a pre-conference bus tour on February 20, and sessions on vegetables, strawberries, blueberries, ornamentals, marketing, and organic marketing. For more information, contact Pamela Mayer at 417-547-7500 or pam621t@smsu.edu or visit http://mtngrv.missouristate.edu.

March 7-8, 2006, Small Fruit & Strawberry Schools ...
... at the Mount Vernon Holiday Inn. For more information, contact Elizabeth Wahle at 618-692-9434 or by email at wahle@uiuc.edu, or Bronwyn Aly at 618-695-2444 or by email at baly@uiuc.edu. As the dates approach, check for information at "News for Southern Illinois Growers" at: http://web.extension.uiuc.edu/regions/hort/.

(Rick Weinzierl (217-333-6651; weinzier@uiuc.edu)

Fruit Production and Pest Management

Tattoos for fresh fruit?

Something caught my eye in ***Parade*** a few Sundays ago – tattoos for fresh produce. This is a "Natural Light Labeling System" that prints on produce with precise control of emitted light by removing the pigment layer from the surface of the produce to reveal a contrasting sub-layer. This removal process has been designed not to penetrate the skin of the produce,

and it therefore neither reduces shelf life nor does it promote decay. The laser can print Product Look-up Code (PLU), Country of Origin Labeling (COOL), Grower Lot Numbers, logos, and any other requested information and can change any of these codes within seconds. Durand-Wayland markets this product and offers the chance to see the Natural Light Labeling System in action through a visit to their facility an hour south of the Atlanta airport, or they have a program whereby you send them fruit to be etched and they overnight it back to you, so you can do your own shelf life tests, etc. For more information, go to http://www.durand-wayland.com/.

Elizabeth Wahle (618-692-9434; wahle@uiuc.edu)

2005 Illinois Apple Insecticide and Miticide Evaluations

The effectiveness of selected insecticides was evaluated in a small plot trial conducted in 2005 at the University of Illinois Pomology Farm near Urbana, Illinois. Four insecticide treatments (Table 1) were evaluated in comparison with an untreated check for controlling fruit injury by codling moth, *Cydia pomonella*, and San Jose scale, *Quadraspidiotus perniciosus*, in 'Red Delicious' apples. Four single-tree replications per treatment were assigned in a randomized complete block design. Sprays were applied in 1,600 ml water per tree from a CO_2-powered backpack sprayer operating at 40 psi, with insecticide concentrations based on the calculation that a single tree at this site represented 0.011 acre. Spray volume (equivalent to 38.5 gal / acre) provided complete coverage. Applications began on 24 May, 2005, approximately 200 degree days (base 50 F) after biofix on 09 May. Subsequent sprays were applied according to the schedule summarized in Table 1. All applications of Assail 30 WSG included 0.25% Damoil (by volume). No phytotoxicity was observed in any of the treatments.

Table 1. Insecticides, rates, and application dates for apples, University of Illinois Pomology Farm, Urbana, 2005.

Treatment	Insecticide and Rate	Application Dates
1	Untreated Check	
2	Assail 30 WSG, 6 oz/a Guthion 50 WP, 2 lb/a	24 May, 08 June, 09 July, 20 July, 16 August 25 June, 03 August
3	Assail 30 WSG, 8 oz/a Rimon 0.83 EC, 40 fl oz/a Guthion 50 WP, 2 lb/a	24 May, 09 July, 16 August 24 May, 09 July, 16 August 25 June, 03 August
4	Calypso 4F, 4 fl oz/a Guthion 50 WP, 2 lb/a	24 May, 08 June, 09 July, 20 July, 16 August 25 June, 03 August
5	Entrust 80 WP, 3 oz/a	24 May, 01 June, 08 June, 15 June, 25 June, 02 July, 09 July, 20 July, 03 August, 16 August, 22 August

Fruit injury was assessed in harvest samples of up to 100 apples per tree taken on 02 September, 2005. Fruits were examined in the laboratory for codling moth stings and tunnels, infestations of San Jose scale, and injury caused by other insects. All larvae found in fruit were examined to confirm that they were codling moth, not oriental fruit moth or other species. The percentages of fruit exhibiting codling moth tunnels and San Jose scale infestations are summarized by insecticide treatment in Table 2.

The neonicotinyls acetamiprid (Assail) and thiacloprid (Calypso) and a combination treatment of Assail plus the substituted urea novaluron (Rimon), were very effective for codling moth. control when coupled with two applications of Guthion to carry control through the end of first and second generation (Guthion applied on 02 July and 03 August). Entrust, an OMRI-listed insecticide that may be used in organic production, was moderately effective when applied more frequently than the other treatments. Plans called for application of Entrust at 7-day intervals throughout the season, but weather and scheduling conflicts did not allow that strict an application schedule. Treatments that included Assail (numbers 2 and 3) also gave control of San Jose scale, at least as reflected by infestations on fruit at harvest.

Table 2. Mean percent fruit with codling moth tunnels and San Jose scale infestations in harvest samples of apples treated with selected insecticides, University of Illinois Pomology Farm, Urbana, 2005.

Treatment	Mean % Fruit with Codling Moth Tunnels	Mean % Fruit with San Jose Scale Infestations
1. Untreated Check	43.4	20.0
2. Assail (5), Guthion (2)	0.7	1.7
3. Assail + Rimon (3), Guthion (2)	0	3.0
4. Calypso (5), Guthion (2)	1.5	12.6
5. Entrust (11)	9.7	14.4

Trees within the plot designated for the codling moth trial described above supported increasing populations of European red mite, *Panonychus ulmi*, by late June and early July. Infestations on 28 June are summarized in Table 3.

Table 3. Percentage of leaves infested with $\geq$ 5 mites per leaf on 28 June, 2005 (mean of 15 leaves per tree over four single-tree reps per treatment).

	1. Untreated Check	2. Assail (5), Guthion (2)	3. Assail + Rimon (3), Guthion (2)	4. Calypso (5), Guthion (2)	5. Entrust (11)
Percentage of leaves with $\geq$5 mites per leaf	30	58	58	48	8

Trees from the Assail, Assail + Rimon, and Calypso treatments were more heavily infested with European red mites than the untreated check or Entrust treatments and were used to evaluate mite control provided by Acramite and Zeal. Acramite 50 WS and Zeal 72 WG were applied at 0.75 lb. and 2 oz. per acre, respectively, in 38.5 gal of spray volume per acre at 40 psi to 3 trees each in a single-tree, randomized, complete block design on 02 July, with one tree per block used as an untreated check. European red mite counts taken on 07 and 22 July (5 and 20 DAT) are summarized in Table 4.

Infestations of European red mite remained high in the untreated check trees through the 20-day post-treatment sampling date. Acramite provided greater immediate control, reducing the population to 0.4 mites per leaf by the 5-day post-treatment counts (in comparison with 4.3 mites per leaf in the Zeal-treated trees). However, by 20 days post-treatment, counts of motile mites on Acramite- and Zeal-treated trees were similar at 0.2 and 0.3 mites per leaf, respectively.

Table 4. Post-treatment counts of motile stages of European red mite, by treatment, on apple leaves, 2005, Urbana, IL.

Date	Untreated Check	Acramite	Zeal
07 July (5 DAT)	31.6	0.4	4.3
22 July (20 DAT)	20.1	0.2	0.3

This work was supported in part by Bayer, Cerexagri, Chemtura, and Dow, and by University of Illinois Hatch Project ILLU-802-365.

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Vegetable Production and Pest management

Notes on Colored Plastic Mulch Trials at the St. Charles Horticulture Research Center

Tomato (variety 'Sunstart'): Plants grown on ground covered with reflective (white-on-black), blue, black embossed, and olive plastic mulches were taller than plants growing on bare ground (control), and on ground covered with clear, yellow, and white plastic mulches 21 days after transplanting (DAT). One month later at 50 DAT, plants grown in white, blue, reflective, and olive plastic mulches were taller than plants in other treatments. Higher marketable yields were observed at first harvest on August 8 (69 DAT) from olive, red, blue, and black smooth plastic mulch plots, but the trend changed in cumulative marketable yields where reflective, red, blue and olive plastic mulch plots had higher yields by the end of the trial. In comparison with black embossed plastic mulch commonly used by many vegetable growers, plots where reflective, red, blue, and olive plastic mulches were used had 1 or more tons/acre higher marketable fruit yield than black embossed plastic mulch plots.

Muskmelon (variety 'Athena'): At 17 DAT, plants grown on ground covered with clear, red, yellow, and black embossed plastic mulches had longer vines than plants in other treatments. One month later (46 DAT), plants in blue, red, olive, black smooth, and black embossed plastic mulch plots had longer vines. Higher yields at first harvest on August 8 (65 DAT) were observed in red, olive, clear, and black embossed plastic mulch plots. Higher cumulative yields were observed in blue, red, black smooth, black embossed, and olive plastic mulch plots.

Pepper (variety 'Boynton'): Plants grown on ground covered with white, yellow, red, and clear plastic mulches were taller than plants in other treatments on June 21 (12 DAT). At 34 DAT, plants grown in reflective, white, blue, and olive plastic mulch plots were taller than plants in other treatments. Higher cumulative marketable pepper yields were observed in olive, white, reflective, and red plastic mulch plots than in other treatments, with a higher proportion of fancy to US No.1 grade fruits in red and reflective mulch plots. Seedlings transplanted in olive, white, reflective, and blue plastic mulch plots had higher marketable bell pepper yield (three pickings) than plants grown in black embossed plastic mulch plots.

Maurice Ogutu (708-352-0109 or by email at ogutu@uiuc.edu)

Sweet corn insects ... corn earworm resistance to pyrethroid insecticides; other insects in sweet corn ears; and results of the 2005 fall European corn borer survey

Sweet corn growers should pay close attention to the information presented below. Two new and distinctly troubling problems may make insect management in sweet corn more difficult in 2006 and/or further into the future. One is at least some level of pyrethroid resistance in the corn earworm, and the other is the presence of the western bean cutworm in Illinois. These new problems, along with an update on European corn borer populations, are the focus of the following articles.

Pyrethroid resistance in the corn earworm

Here's what we (entomologists in the Midwest) know ...

- Timely sprays of pyrethroid insecticides prevented corn earworm infestations in sweet corn ears in many fields where pheromone trap captures of moths indicated that pressure was moderate to high in 2005. But ...
- In small-plot trials conducted to evaluate new and standard insecticides for control of ear-infesting pests, levels of corn earworm control have declined from well over 90 percent to well below 50 percent (with "percent control" based on numbers of earworms in ears and/or percentage infested ears in treated versus untreated plots).
- An increasing number of growers have reported unacceptable numbers of "worms" in ears at harvest in late August and September, even when they have followed a tight spray schedule, spraying every 2 or 3 days with a pyrethroid such as Warrior, Capture, Baythroid, or Mustang Max. It is true that over the last several years we have always gotten a few such reports, and it's also true that closer investigations sometimes revealed that spray timing was inadequate in at least a few instances. In general in the past (before 2004) we have concluded that spray timing and coverage – not insecticide resistance – were the causes of problems. The same is not true for several control failures reported in 2004 and 2005.
- Corn earworm larvae were collected in August or September, 2003 - 2005, from one or more locations in Illinois, Indiana, Wisconsin, and Minnesota and sent to a laboratory in Louisiana (Louisiana State University) to establish colonies for insecticide bioassays (tests to determine susceptibility or resistance to particular insecticides). Bioassays have shown increasing levels of survival of corn earworms at doses that cause nearly 100 percent mortality in a susceptible population. Colonies derived from Midwest collections show levels of resistance similar to those seen in southern

populations. (Remember that every year our corn earworm populations result primarily from summer migration of adults northward from overwintering sites in southern states; corn earworms do not overwinter successfully in most of the state or the region. That means that selection for resistance by pyrethroid use on corn and soybeans in the south plays a role in the genetics of populations that infest corn here.)

- Resistance to one pyrethroid almost certainly will mean resistance to all the pyrethroids used in sweet corn and other vegetables. Switching/rotating among Capture, Baythroid, Warrior, and Mustang Max (or Pounce and Ambush) is NOT likely to provide any benefit.

So ...what does this mean for 2006?

Pyrethroids still are the best insecticides for corn earworm control where resistance is not a problem. Until we know more, using Baythroid, Capture, Mustang-Max, or Warrior is still recommended for earworm control. Operating a pheromone trap to monitor earworm moth flights and keeping daily records of moth counts and insecticide applications is essential for interpreting the success or failure of control programs. Planning ahead to use alternatives to pyrethroids for earworm control if needed is also recommended. Alternatives include planting Bt sweet corn hybrids, especially for late-season harvests when earworm pressure is greatest, and switching to or tank-mixing insecticides other than pyrethroids. Non-pyrethroid insecticides registered for use on sweet corn for earworm control include Sevin, SpinTor/Entrust, Lannate, and Larvin. None of these insecticides is as effective as any of the four pyrethroids listed above where earworm populations are susceptible to pyrethroids, but where control failures occur as a result of pyrethroid resistance, they will be valuable as alternatives or tank-mix components.

Keep your eyes and ears open as the 2006 season progresses. Entomologists in the region do not want to "cry wolf" unnecessarily, nor do we want to keep silent when a serious problem may be developing. To complicate everything, at least in Iowa and northern Illinois, western bean cutworm may also be a part of any unexpected "worm" problems in sweet corn and field corn ... continue on to the next article for news on this insect.

Rick Weinzierl (217-333-6651; weinzier@uiuc.edu)

Insects in the ears of sweet corn ... Were they corn borers, corn earworms, fall armyworm, or western bean cutworm?

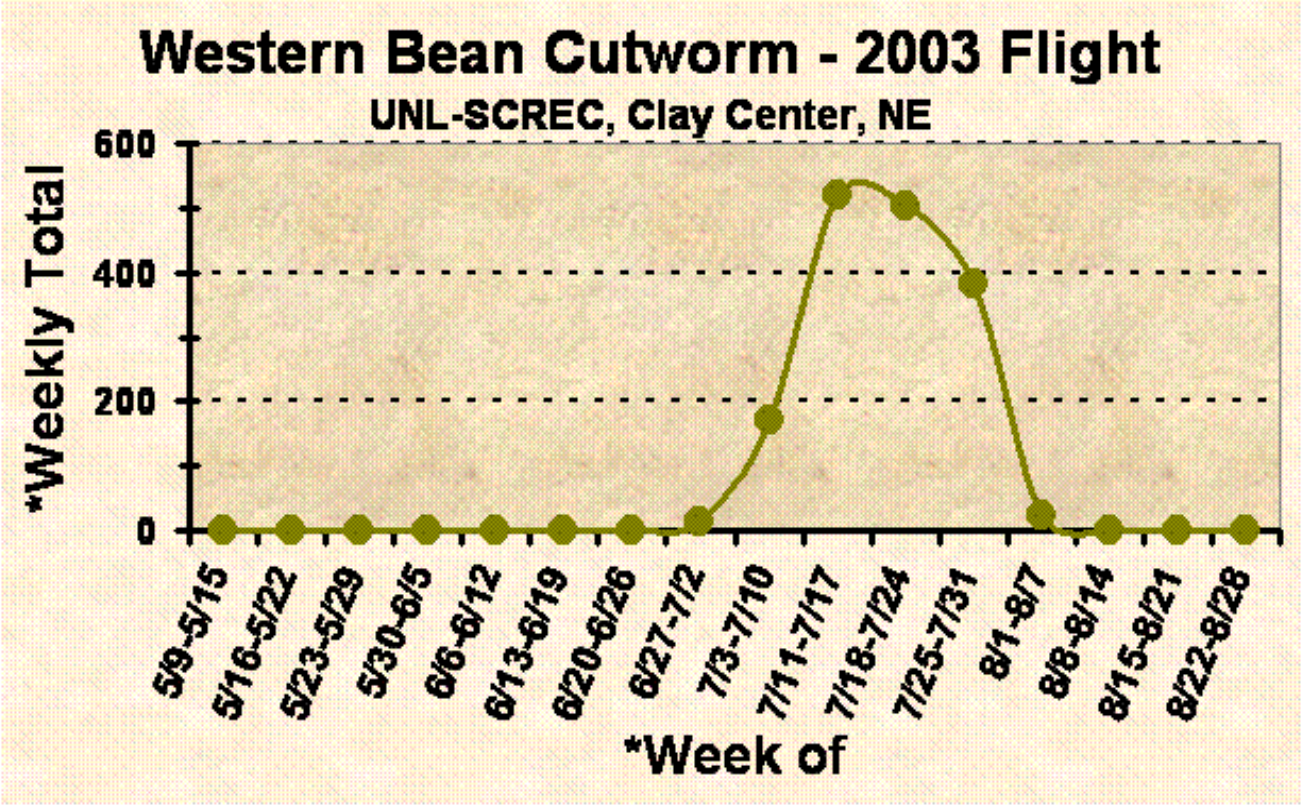
Yes.

OK, so "yes" is not a complete answer to the question posed in the heading. But it is accurate ... during August and September of 2005, at least four Lepidopteran species were common in sweet corn and field corn in portions of Illinois. Each year this newsletter provides detailed recommendations for monitoring and controlling corn earworm and European corn borer. Fall armyworm, though less common, is also a familiar pest. What's new on the scene in is western bean cutworm. This insect has spread across Iowa and become more common there over the last 4 to 5 years, and in 2005 it was detected across northern Illinois, all the way to the Indiana border.

Western bean cutworm adult and larva. (Photos courtesy of the University of Nebraska)

A mid- to late summer pest of corn, western bean cutworm moths begin to emerge in early July. Using a 50-degree F threshold temperature and a May 1 starting date to count degree-days, moth flight peaks at about 1420 degree-days. An example of flight timing from Clay Center, Nebraska, in 2003 is presented below. After hatching, larvae feed primarily on silks, tassels, and developing kernels. Larvae of the western bean cutworm are not cannibalistic and several larvae may infest

one ear of corn. Entry to corn ears is gained through silk channels or by chewing through ear husks causing injury to the tip, base, and sides of the ear. Larvae will feed on kernels until about mid-September when they exit out the corn husks.



In 2006, we will operate yet more pheromone traps for western bean cutworm than we did in 2005, and as the time for larval feeding approaches, we'll be sure to make note of it in this newsletter. Illinois sweet corn growers, especially those in western and northern Illinois, should be prepared to use pyrethroid insecticides to control this insect even if sprays are not needed for corn earworm or European corn borer at the same time.

Kelly Cook (217-333-4424; kcook8@uiuc.edu) and Rick Weinzierl (217-333-6651; weinzier@uiuc.edu)

Annual European Corn Borer Survey Results

(This summary was first published in the *Illinois Pest Management and Crop Development Bulletin*.)

Results are in from our annual fall survey of second-generation European corn borer populations. Continuing with the method we used in 2004 to present these results, a table of averages of numbers of European corn borer larvae per 100 plants and percentage infestation in counties and crop reporting districts is not printed here. Instead, the results are detailed in a PowerPoint slide set the can be accessed on the IPM Web site at:

http://www.ipm.uiuc.edu/fieldcrops/insects/european_corn_borer/index.html

This site is the European corn borer page on the IPM web site. Look for and click on "Fall Survey 2005" under the "Related Links" category. A further discussion on how the fall survey is conducted can be found on the fact sheet labeled "Fall Survey." The PowerPoint slides include the following for each crop reporting district in Illinois:

- Average number of European corn borer (ECB) larvae per 100 plants for the counties surveyed within each crop reporting district
- Average percentage infestation of ECB for the counties surveyed within each crop reporting district
- Percentage infestation of ECB in 10 fields within one of the counties surveyed within the crop reporting district (prepared as an example of variability of infestation within a county)

On most of the slides, the averages for the crop reporting district (orange) and the state (red) are included. The slide set concludes with four slides that depict (1) the average number of ECB per 100 plants for all crop reporting districts and the state, (2) the average percentage infestation of ECB for all crop reporting districts and the state, (3) a map of Illinois depicting the average number of ECB per 100 plants in each of the counties surveyed, and (4) a map of Illinois depicting the average percentage infestation of ECB in each of the counties surveyed.

We invite you to use the information provided in this PowerPoint slide set. We ask only that you acknowledge the University of Illinois Department of Crop Sciences if you use the information in any of your educational meetings.

After low populations in 2004, European corn borer populations rebounded and were higher in 2005. The average number of second-generation ECB per 100 plants in Illinois in 2005 was 34.4, more than double the number in 2004 (15.6). Average percent infestation of corn plants was 24.2, also higher than 17.1 percent infested in 2004. Remember, this does not necessarily equate to economic infestations of ECB in 2006. Many factors affect survival of ECB, not the least of which are time of planting and weather conditions during moth flights. The number of corn borers that will overwinter throughout the state are higher than in 2004, but are still low, especially compared to historic numbers (Figure 1).

This survey would not be possible without the help of University of Illinois Extension educators (IPM and Crop Systems), graduate students, and faculty and staff in the Department of Crop Sciences. We would like to thank these individuals for helping us to keep our record of European corn borer populations intact from 1943 through 2005 (with the exception of 2 years during which the survey was not conducted). Without their willingness to help, such a time-consuming and labor-intensive task could not be completed. If you have any questions about our results or use of the slides we have provided, please don't hesitate to contact us.

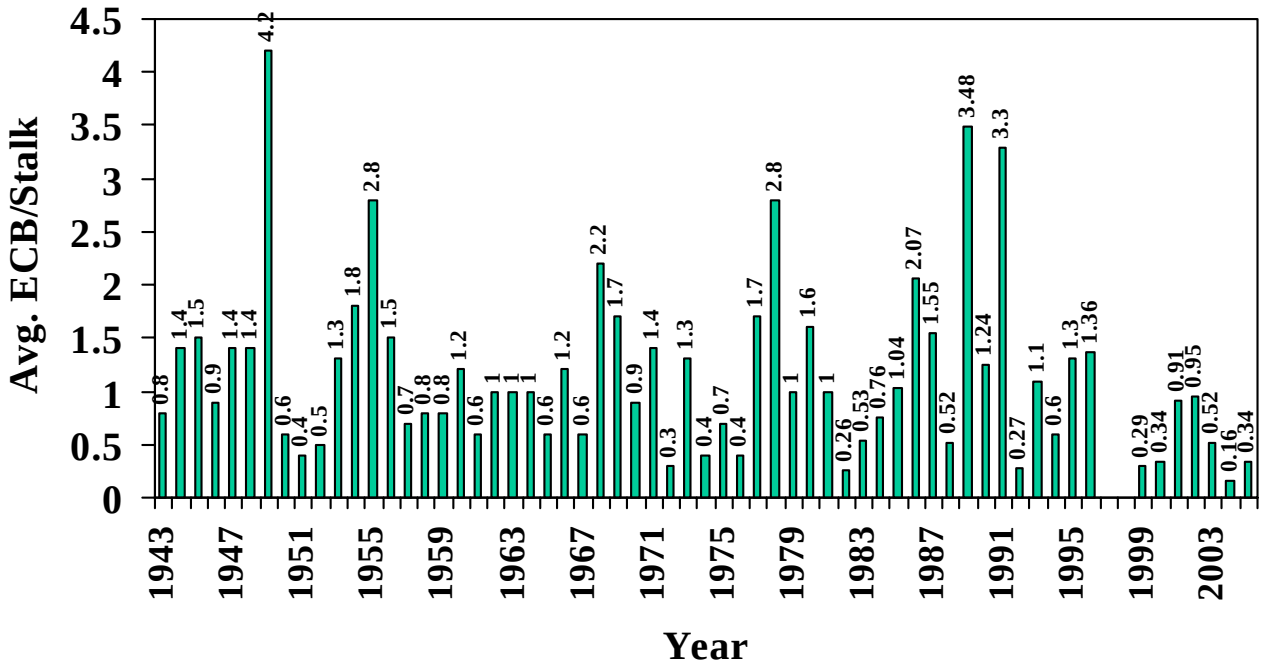


Figure 1. Historic summary of European corn borer per plant in Illinois during annual fall survey, 1943-2005 (graph courtesy of Robert Bellm, University of Illinois Extension).

Kelly Cook (217-333-4424; kcook8@uiuc.edu)

Why do certain plants survive a very cold winter while others don't?

December's three weeks of very cold weather reminded me of my first job. After graduating from Oregon State University in 1984, I was hired as a postdoctorate by the USDA Office in Orlando, Florida, to work on citrus cold hardiness. Interestingly, on Christmas day, 1983, central Florida was hit with the costliest winter freeze in the state's history. An estimated $1 billion loss to the citrus industry was attributed to that freeze. If that wasn't enough, on January 21, 1985, the Florida citrus industry was hit with yet another freeze that basically wiped out the industry from that part of the state. I recall a crisp but comfortable morning that day, but by noon the temperature had dropped to18 ºF in less than two hours. The economic hardship from these two freezes forced growers to sell and move further south. Now most of that area is covered with condos and strip malls. The most interesting observations that I made from the freeze of 1985 was that growers that pruned their trees heavily during the summer of 1984 to renew growth from the 1983 Christmas day freeze, suffered the greatest tree losses. Another observation was that once in a while I saw one or two trees in the middle of some groves that looked healthy, as if the freeze had never occurred.. In this article I will try to explain how trees respond to winter temperature and what makes certain trees survive while others don't.

The subject of freezing injury has been studied on and off over many centuries, but probably more so in the 1960s 70s because of financial support from the USDA and the enthusiasm of a group of researchers at University of Minnesota. Before I start writing about winter injury, however, I would like to point out that plants in general are not fond of cold weather. Surviving the winter months is costly to plants that wait it out. In the temperate areas, plants (temperate trees) avoid freezing injury by shedding their only source of food, their leaves and enter a stage of dormancy or absence of visible growth to avoid potential starvation and death. Some researchers divide dormancy into two stages, rest and quiescence. Rest is the stage where plants will not grow even if the weather warms up for a relatively short period of time. This stage is usually reached in the middle of winter. Quiescence on the other hand is the failure of plants to grow because of unfavorable weather conditions. However, if the weather warms up they will start to grow. Plants enter into this stage usually in early fall, late winter, and early spring.

In many plants dormancy plays an important role in their ability to cold harden. Plants that are capable of withstanding winter (temperate plants) enter into dormancy by increasing the production of certain hormones, such as abscisic acid (ABA), and by reducing the levels of other hormones, such as GA. A high level of ABA causes leaves to drop. Plants entering dormancy also reduce the amount of free water inside their cells. As we will find out later, when free water freezes it forms ice crystals that injure the cells. The general idea is that plants that can survive low temperature are those that accumulate more ABA and loose more water than those that don't. But there is much more to it than that.

Another important factor in the ability of plants to withstand low temperature is hardiness. Cold hardiness or cold acclimation is a physiological change in the plant that allows it to tolerate an otherwise injurious temperatures. Cold hardiness is believed to be genetically controlled, especially in acclimated plants. Hardiness occurs when a plant is acclimated by exposing it for a few days to temperatures slightly above those that normally cause injury. The cue for acclimation and eventual hardiness is cool temperature and day length. Plants start to acclimate when the days get shorter and cooler in the fall. Insect models offer the best example of cold hardiness and acclimation. Survival of pharate adults of the flesh fly *Sarcophaga crassipalpis* increased to 91% when they were placed at 0˚C for only 2 hours and then transferred to -10˚C. Acclimation can also be seen in tender plants like tomato or pepper when the temperature drops gradually versus rapidly. When the temperature drops gradually these plants can survive a few degrees lower than when there is a sudden drop in temperature.

Several mechanisms have been proposed for plants that tolerate freezing. Some plants tolerate freezing by expelling water outside the cell into the extracellular spaces; others use a process known as supercooling; and yet others lower their freezing point by accumulating a type of antifreeze in the form of proteins, other cryoprotectants, or by dehydration of the cells. However, most physiologists agree that the crucial factor in winter injury is not low temperature, per se, but ice crystals that form inside the cells causing their rupture. For any living organism to survive winter damage it has to prevent ice crystals from forming inside the cells. However, water freezing in the spaces between the cells (outside the cells) does not kill plants unless it is combined with ice forming inside the cells. Ice is formed around nucleating agents, which are very tiny particles inside the tissue. It is the same principle for rain formation and cloud seeding. Rain droplets form around microscopic particles—dust, smoke, salt crystals, soil and other materials that are present in the atmosphere to form rain. Inside living cells, water also condenses around microscopic particles to form ice crystals. Fortunately, there aren't many floating microscopic particles in living organisms, but unfortunately it takes only a few ice crystals to form for the plant to freeze.

Interestingly, studies have shown that Antarctic micro-arthropods, only a few millimeters long, are the largest terrestrial animals that live year-around on the Antarctic Continent. They survive low temperatures by a process known as supercooling, which involves reducing their freezing point to as low as -30˚C in the winter by emptying their gut of food. However in the summer, when they start feeding, these insects were found to freeze at about -6˚C, because of ice nucleating agents found on the particles of food in their gut. More recent studies have also shown that, in some organisms, digestive enzymes destroy ice nucleating sites on the surface of food particles inside the guts and that allow them to survive lower temperatures. The process of supercooling can also occur in plants as well, especially in plants that have small cells, limited intercellular spaces and plants that have low free water content. Remember the few orange trees in central Florida that survived the freeze even though every tree around them had died. These trees survived because they were able to supercool. There is nothing magical about those trees, except than they were able to supercool at that time. Supercooling occurs when the free water in the cell does not freeze at subfreezing temperatures. Most likely, these trees would die if they were exposed to the same temperature, unless they were able to supercool again. The reason those trees were able to survive may have been due to very limited free water in their cells at that time. Unfortunately, supercooling can only proceed to a certain steady-state level, which varies seasonally, depending on the condition of the plant, but after which freezing and death will occur. Supercooling is also a phenomenon of freezing rain, but that is a different subject. In the next issue, I will write about how to reduce freezing injury in your trees.

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This issue's words of wisdom (well, not always wisdom, and usually not true) ...

- On a t-shirt in Key West Florida ... "I am NOT 50 years old ... I'm 18, with 32 years of experience."

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